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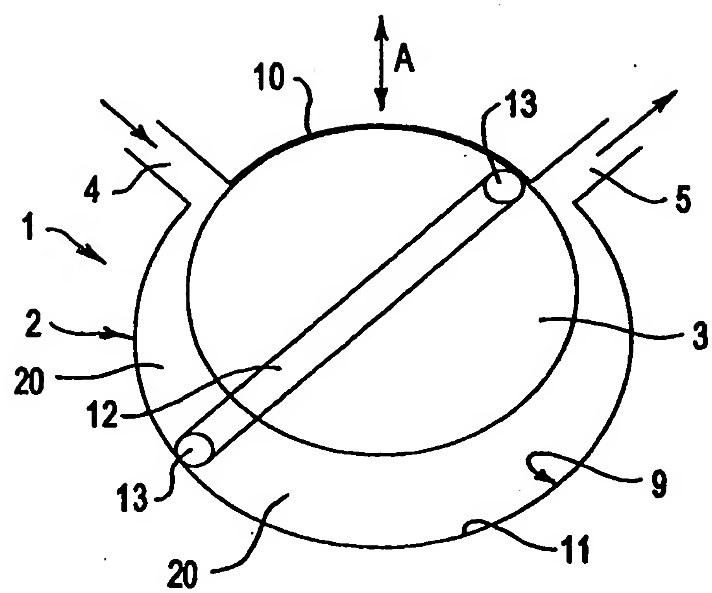
(54) Title: POSITIVE DISPLACEMENT PUMP

(57) Abstract

A vane–type rotary fluid displacing device (1) including an external member (2) co–operating with an internal member (3), the members being relatively rotatable about a common axis, the external member (2) having an internal peripheral surface and the internal member (3) having an external peripheral surface, the surfaces being opposed, one of which peripheral surfaces has a sinuous profile (9) additionally including first and second arcs (10, 11), the other peripheral surface having a substantially circular profilem wherein said member having the substantially circular profile has at least one diametrically opposed vane (12) slidably received therein; said first arc (10) having a radius of curvature fractionally greather than a distance from the axis of rotation to said external peripheral surface of said internal member; said second arc (11) having a radius of curvature larger than that of said first arc (10) by the extent of the maximum excursion of said vane (12) beyond said other peripheral surface; wherein said vane (12) is adapted to continuously contact and sweep the peripheral surface of the other member, such that upon relative rotation of the members, the or each vane (12) slides in the member having said other peripheral surface as the vane sweeps said one peripheral surface; wherein the or each vane (12) together with said peripheral surfaces form a plurality of chambers (20), and an inlet (4) provided in one said chamber and an outlet (5) provided in another said chamber whereby, in use, fluid may be drawn into said one chamber (20) through said inlet (4) and discharged from said other chamber through said outlet (5) by the sweeping action of said or each vane.



POSITIVE DISPLACEMENT PUMP

FIELD OF THE INVENTION

This invention relates to a positive displacement pump. A pump in accordance with the invention is particularly suitable for pumping liquids with entrained detritus or like matter, for example slurries, effluent or bilge water. A pump in accordance with this invention is also particularly suitable for functioning as a ventricular assist device. It will be convenient to hereinafter describe the invention with reference to the example uses mentioned above, but it is to be appreciated that the invention is capable of broader application.

BACKGROUND OF THE INVENTION

A known vane pump is made by providing a housing with a sinusoidal contour, one sine wave being performed by a point locus. As the point rotates, the centre around which the point executes its simple harmonic motion (SHM) is also the centre for a cylindrical rotor of the pump. Such a pump has been described in my earlier Australian Patent Specification No. 423669 (43288/68), the entire disclosure of which is incorporated herein by reference. The specification discloses a fluid displacing machine or pump having a rotor member and a stator member relatively rotatable about a common axis. One of the members has a peripheral profile that is sinuous, opposed to which the other of the members has a peripheral profile that is circular. The contour of the sinuous profile generates an odd number of evenly spaced chambers. A feature of the sinuous profile is that the diametral distance between its opposite profile surfaces is constant. At least one diametrally disposed vane is slidably mounted in the circular member and is adapted to sweep the sinuous profile of said one member on rotation of the circular member, there being inlet and outlet passages leading into and out of each chamber respectively, whereby upon relative rotation of the members pumping and/or compressing action is promoted.

Furthermore, sealing means between the vane and the sinuous profile, and pressure-assisted sealing and automatic wear take-up means for the relatively moving surfaces of the machine are disclosed.

The formula for a curve described by a point P, performing n simple harmonic motions as it rotates in a complete circle around a centre O is derived below with reference to Figure 1 of the accompanying drawings which is an amended version of Figure A of AU 43288/68.

Let r_1 be the radius vector defining the position of P, the centre of curvature of the vane end.

b = Radial distance from centre of rotation to mean position S of the S.H.M. of point P.

a = Radial distance to nearest point of S.H.M.

θ_1 = Angle of deflection of rotating radius from the datum line O-J.

The broken line in Figure 1 indicates the curve drawn by point P performing 3 S.H.M.'s while rotating in one complete circle (ie. n=3).

Consider point P as commencing its motion at J. As it rotates an angle θ from the datum line about o the point N - whose projection on the radius vector defines the S.H.M. - rotates through an angle 3θ.

Let $r_1 = OP = OS + SP$ ....(1)

Now angle X-S-N= 3θ-90°

$\therefore$ angle S-N-P = 3θ-90°

$$\sin(S\text{-}N\text{-}P) = \frac{SP}{SN}$$

$$\text{ie } \sin(3\theta - 90) = \frac{SP}{SN} = \cos 3\theta$$

$\therefore SP = SN \cos 3\theta$

Now SN = SM = OS - OM

And OS = b, OM = a

$\therefore SP = b\text{-}a \ \cos 3\theta$ ....(2)

Substitute (2) into (1):

$r_1 = b + (b-a)\cos 3\theta$

Should the vane ends be in the form of an arc the formula for the housing contour which would ensure that part of the arc surface and the housing are in close contact is more complicated as described in more detail in AU 43288/68 and incorporated herein by reference.

However, if the housing is machined with a rotary cutter whose centre follows the simple formula and whose radius is the same as that of the arc on the vane end, then the housing will conform to the required shape.

It is a disadvantage of a housing contour of the shape described that it has a limited area of the close contact with the circular member or rotor thus increasing the likelihood of fluid escaping past the contact area and leaking into another chamber of the pump.

Accordingly, it is an object of this invention to provide a simple and efficient vane pump which at least partially overcomes this disadvantage.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a vane-type rotary fluid displacing device including an external member co-operating with an internal member, the members being relatively rotatable about a common axis, the external member having an internal peripheral surface and the internal member having an external peripheral surface, the surfaces being opposed, one of which peripheral surfaces has a sinuous profile additionally including first and second arcs, the other peripheral surface having a substantially circular profile, wherein said member having the substantially circular profile has at least one diametrically opposed vane slidably received therein;

said first arc having a radius of curvature fractionally greater than a distance from the axis of rotation to said external peripheral surface of said internal member;

said second arc having a radius of curvature larger than that of said first arc by the extent of the maximum excursion of said vane beyond said other peripheral surface;

wherein said vane is adapted to continuously contact and sweep the peripheral surface of the other member, such that upon relative rotation of the members, the or each vane slides in the member having said other peripheral surface as the vane sweeps said one peripheral surface;

wherein the or each vane together with said peripheral surfaces form a plurality of chambers; and

an inlet provided in one said chamber and an outlet provided in another said chamber whereby, in use, fluid may be drawn into said one chamber through said inlet and discharged from said other chamber through said outlet by the sweeping action of said or each vane.

In the fluid displacing device there is an area of very close juxtaposition, such as between about 0.125 to 2 mm, or substantial contact, between the circular member and the housing contour. A larger area of contact or close juxtaposition between the circular member and the housing contour is desirable because the greater the contact area, the less fluid is likely to escape past the contact area and the easier it is to seal the chambers from each other. A larger area of contact can be achieved if two arcs, radial to the rotor centre are inserted into the housing contour. One arc has a radius fractionally larger than that of the rotor and the other arc has a radius larger than that of the said one arc by the extent of the maximum excursion of the vane beyond the rotor. The radial arcs are connected to each other by two half sine waves. Each half sine wave is defined by the formula $r=b+(b-a)\text{Cos } n\theta$ where these terms are to be understood as they have been previously defined. n represents the number of sine waves the point P could perform in one rotation in the absence of the radial arcs. For example, should each arc subtend an angle of 90° at the centre when two sine waves could be performed by the point P in the absence of the arcs and the formula for the half sine waves becomes $r=b+(b-a)\text{Cos } 2\theta$. Or, if, as in Figure 1, three sine waves could be performed by P, the formula becomes $r=b+(b-a) \text{ Cos } 3\theta$. The enlarged area of contact between the housing and rotor allows the pump to function with moderate separation between these surfaces.

Accordingly, there is provided a vane type rotary fluid displacing machine comprising an external member such as a housing cooperating with an internal member such as a rotor. The members are relatively rotatable about a common axis, the external member having an internal peripheral surface and the internal member having an external peripheral surface, the surfaces being opposed. One of the peripheral surfaces has a sinuous profile to which has been added two arcs each having a radius taken on the centre of the rotatable

member, one arc having a fractionally longer radius than that of the rotatable member. The opposite arc has a radius larger than that of said one arc by the extent of the maximum excursion of the vane beyond the rotor. The other peripheral surface has a substantially circular profile having at least one diametrally opposed vane slidably mounted therein and adapted to continuously contact and sweep the peripheral surface profile of the other member to form chambers, so that upon relative rotation of the members the or each vane slides in the circular member as the vane follows the peripheral surface profile. Inlet and outlet passages lead into and out of each chamber, whereby fluid is alternatively drawn into and discharged from the chambers by the sweeping action of the vane or vanes.

Optionally the external member may be movable relative to the internal member. Typically any such movement would be restricted to movement in a radial direction. This permits separation of the rotor from the housing when for example solid material is forced between the adjacent surfaces of the rotor and housing, without obstructing operation of the pump. Relative movement of the external and internal members is particularly advantageous where the pump is used for pumping fluids containing debris or detritus, for example, pumping bilge, sewage, sludge etc.

The relative movement of the external and internal members is less important, and in some cases, undesirable, where the pump is being used as a ventricular assist device. In this application, the fluid being pumped is blood, which does not normally contain detritus. Furthermore, a moveable housing may result in leakage of fluids from one chamber to another.

Further, resilient biasing means may be provided for returning the housing to its original position when the obstruction has been removed. Typically, straps, springs or even the force of gravity may be used to bias the housing back to its original position. In one embodiment, the pump's housing is spring loaded to allow the passage of relatively coarse debris, such as up to 5mm, between the rotor and the housing, after which the housing is biased back to its original position.

It is preferred that the rotor abuts or is adjacent to the peripheral surface profile of the housing along said one arc and that the inlet and outlet ports are placed respectively before and after said one arc.

It is further preferred that rollers are placed at each end of the vane to reduce wear of the vane tips.

The present invention also provides a ventricular assist device including a pump as defined broadly above. Such a ventricular assist device may incorporate any one or more of the optional features defined above. The device may be used as a left ventricular assist device or for use in total cardio-pulmonary bypass. The device may even be used as an artificial heart.

One embodiment of a ventricular assist device includes an integral housing and does not include means facilitating movement of the external member relative to the internal member or rollers at each end of the vane.

In a preferred form, the inlet and outlet passages of a ventricular assist device project away from the housing substantially parallel to each other.

The ventricular assist device may be located external to the patient. This would typically occur where the device was only being used as a "bridge to transplantation" or in acute treatment for a failing heart.

Alternatively the ventricular assist device may be implanted into a patient, for example in the thoracic cavity or abdomen. It is envisaged that an implanted device could be driven by an electro-mechanical actuation means which transfers energy transcutaneously via an inductance loop.

The present invention further provides a pump defined broadly above when used as a ventricular assist device. Such a pump may include any one or more of the optional features defined above.

It is preferred that the materials from which the ventricular assist device is made are biocompatible and exhibit low wear. The vane is preferably constructed from Teflon (TM) dispersed in acetal resin, the rotor from Teflon glass (ie polytetrafluoroethylene impregnated with 25% glass fibres), and the housing from polycarbonate.

Teflon glass is advantageous due to its very low water absorptive properties, ie less than 0.01 ml/g/24 hr immersion. Teflon dispersed acetal

resin and polycarbonate also have low water absorptive properties at 0.06 and 0.15 ml/g/24 hr immersion, respectively. The wear and thermal expansion properties of these materials are also beneficial. Acetal resin impregnated with 20% Teflon moving against polycarbonate (under standard conditions) results in a wear factor of 26 for the stator surface and 380 for the moving surface. The coefficients of expansion of Teflon glass, Teflon dispersed in acetal resin and polycarbonate are 10, 11 and 12 m/m/°C x 10^{-5}, respectively.

The ventricular assist device may be driven in a continuous mode or a pulsatile mode. In the pulsatile mode, the pump operates so as to simulate normal systolic and diastolic periods of a natural heart.

The invention also extends to a pump having a housing defining two chambers each of which has a rotor and vane arrangement associated therewith. It is preferred that the two rotors are driven by the same drive means via a single drive shaft.

DESCRIPTION OF DRAWINGS

A pump according to the invention may take any one of a variety of forms. It will be convenient to hereinafter describe the invention in greater detail by reference to two particular embodiments thereof as shown in the accompanying drawings. The particularity of these drawings is not to be understood as superseding the generality of the preceding description.

In the drawings:

Figure 1 is a schematic view of a curve made by a point P performing three simple harmonic motions while rotating in a complete circle about O.

Figure 2 is a schematic view of a pump in accordance with a first embodiment of the invention;

Figure 3 is a perspective view of the pump of Figure 2 assembled;

Figure 4 is a cross-sectional view of the pump of Figure 3 taken across its axis;

Figure 5 is a cross-sectional view of the pump of Figure 3 taken along its axis;

Figure 6 is a cross-sectional view through a pump in accordance with a second embodiment of the invention, taken across its axis;

Figure 7 is a perspective view of the pump of Figure 6;

Figure 8 is a cross-sectional view taken across the axis of a variation of the pump of Figure 6; and

Figure 9 is a cross-sectional view taken along the axis of the pump of Figure 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The pump in accordance with the first embodiment shown in Figures 2 to 5 is described immediately below.

The pump 1 includes an external member which is a housing 2 within which an internal member which is a rotor 3 is received. A vane 12 is located slidably within the rotor 3. An inlet 4 directs fluid to be pumped into the housing 2 and an outlet 5 spaced from the inlet 4 on the housing 2, directs pumped fluid out of the housing 2. Figure 2 shows the inlet 4 and outlet 5 projecting radially outwardly away from the housing 2.

The housing 2 is in the form of a flattened cylinder having two major surfaces 6 and 7 separated from each other by a substantially cylindrical wall 8. The cylindrical wall 8 is slidably mounted between the major surfaces 6 and 7 by means of bolts 16. As shown in the drawings each end surface 6 and 7 may have a cover mounted thereon which is removable from the remainder of the housing 2. Each cover may have a poly-tetrafluoroethylene facing which abuts against the wall 8.

The housing 2 has an internal peripheral surface configured as a sinuous profile 9 to which has been added two arcs. A first arc 10 has a radius taken on the centre of the rotor 3 and fractionally longer than the radius of the rotor 3. The second arc 11 has a radius taken on the centre of the rotor 3 and longer than the first arc 10 by the extent of the full excursion of the vane beyond the rotor 3. Each arc subtends an angle of about 90°C. The two arcs 10, 11 are separated by half sine waves. The length of the arcs 10, 11 is arranged to suit the application for which the pump 1 is intended. The profile 9 is configured such that a fixed length vane 12 may be used, each end of which continuously contacts the housing profile as the vane 12 rotates.

In the pump shown in the drawings, the vane 12 has cylindrical rollers 13 at each end thereof to reduce wear thereof. However it is to be appreciated the feature of the rollers 13 may not be incorporated in some embodiments of the invention.

The housing 2 may include support means 15 for supporting the pump on or anchoring the pump to a support surface. For example, as shown in Figure 3, such support means 15 may be in the form of an L-shaped bracket.

The pump may include means facilitating some limited movement of the housing 2 relative to the rotor 3 in a radial direction. For example, the pump may be adapted, via the arrangement of bolts 16 fastening the end covers to the wall 8, to permit movement of the wall 8 in the direction indicated by the arrow A (Figure 2). That is, the housing 2 is able to move radially apart from the rotor 3 at the area of very close juxtaposition between the rotor 3 and the housing 2 (i.e. at arc 10). This movement may occur in the event of excessive pressure or during the entrapment of debris between the rotor 3 and housing 2. This feature results in the pump being able to pump fluids containing entrained foreign matter and the outlet 5 can be obstructed without, or with minimal, damage to the pump.

Resilient biasing means in the form of springs 17 may be provided to return the wall 8 of the housing 2 to its original position relative to the rotor 3. As shown in the drawings such springs 17 may be passed between two bolts 16 around the wall 8 so as to urge the wall 8 back to its original position. Each end of spring 17 is hooked onto the shaft of a bolt 16. Typically such displacement of the wall 8 away from the rotor 3 is caused in the first instance by excessive pressure, entrained detritus or the like.

As is indicated in the drawings, the inlet 4 and outlet 5 are typically positioned on either side of the shorter arc 10 of the housing 2.

The rotor 3 is drivably coupled to a drive shaft 18 which in turn is coupled to a drive means (not shown) which may take any suitable form. The shaft 18 is supported on bearings 19 which locate the rotor 3 within the housing 2.

In use, the rotor 3 shown in Figure 2 is rotated in an anti-clockwise direction by the drive means. Obviously other rotors may be rotated in a

clockwise direction. As it rotates, the vane 12 sweeps the internal peripheral surface profile of the housing 2. The vane 12 slides in the rotor 3 as opposed ends thereof maintain continuous contact with the internal profile 9 of the housing 2. The vane 12 together with the rotor 3 and the internal profile 9 of the housing 2 define a plurality of chambers 20. Fluid is drawn into each chamber 20 through the inlet 4 and forced out through the outlet 5 by rotation of the rotor 3 and associated vane 12. In this manner a positive displacement type pumping action is effected.

Two pumps in accordance with a second embodiment of the invention are shown in Figures 6 to 10. Unless otherwise indicated the same reference numerals in these drawings refer to the same components as in Figures 2 to 5. The structure and function of these pumps is very similar to that shown in Figures 2 to 5 and the following description focuses on the differences between the two embodiments.

The pumps shown in Figures 6 to 10 are designed for use as a ventricular assist device (VAD). The pumps are compact. The housing 2 of each pump is of polycarbonate, the rotor 3 of teflon and fibreglass, and the vane 12 of teflon dispersed in acetyl resin. Naturally however other biologically acceptable materials may be used for these components.

The pumps are designed for use both as an external ventricular assist device and as an implantable and thus internal device. In use as an external ventricular assist device, the pump may act as a "bridge to transplantation" or in acute treatment for a failing heart. In its application as an implantable device, the pump may act as a functional replacement for the left ventricle of the heart. When such a device is implanted, electro-mechanical actuation means may be used to achieve transcutaneous energy transfer, for example via an inductance loop.

It is to be noted that the pumps shown in Figures 6 to 10 do not include means for facilitating movement of the housing 2 relative to the rotor 3. Further it is to be noted that the pump shown in Figures 9 and 10 does not have rollers 13 at each end of the vane 12.

In use, the pumps illustrated in Figures 6 to 10 function in substantially the same way as the pump illustrated in Figures 2 to 5. Figures 8a, b and c illustrate the principle of the pump's action.

In Figure 8(a) (b) and (c) the pump 1 is illustrated with the rotor 3 and vane 12 rotating in a clockwise direction. Figure 8(a) shows blood (indicated as shaded area) being drawn into the inlet 4 by the action of the vane 12. As the leading end 12a of the vane 12 passes the inlet 4, it creates a zone of low pressure in the chamber 20a which draws blood into chamber 20a. With further rotation of the vane 12, the trailing end 12b (Figure 8(b)) passes the inlet 4, thus sealing the blood in chamber 20a. The blood filled chamber 20a is moved towards the outlet 5 with further rotation of the vane 12, and the blood is expelled through the outlet 5.

Although such a pump is not illustrated in the drawings, it is to be appreciated that a modified pump having two pumping mechanisms driven by the same drive shaft could be used as a biventricular assist device. The two pumping mechanisms could be adapted to have different stroke volumes by appropriate configuration of the respective surface profiles 9. Naturally a biventricular assist device could function as a total artificial heart.

It is an advantage of a pump of this design that it provides improved sealing between the rotor and the internal profile of the housing. This is achieved by the inclusion of arcs in the profile of the interior surface of the housing. In particular, the arc with the smaller radius of curvature enables a relatively large area of contact between the rotor and the internal peripheral surface of the housing, which lessens the possibility of fluid leaking past the area of contact. This in turn improves the seal between chambers in the pump. Further the configuration of the internal profile of the housing so as to provide a constant diametral length through the rotor centre allows fine clearances between the vane and the housing.

It is a further advantage of a pump of this design that the stroke volume can easily be changed to suit different applications. Further it has a relatively simple and compact design with few moving parts with the consequence that it is relatively inexpensive to make.

An advantage of providing a ventricular assist device which is a pump in accordance with this invention is that it eliminates the use of valves which are a weak point in existing ventricular assist devices. Further the compact design of the pump enables its implantation in either the thoracic cavity or abdomen of a patient. Further the device can be operated in continuous or pulsatile mode and the rotor could be magnetically coupled to the drive means. Further it is envisaged that the implanted pump may be driven transcutaneously by an external power source without having tubing or wires passing through the skin of a patient. Finally a ventricular assist device according to this invention would be substantially less expensive than known ventricular assist devices.

It is to be understood that various alterations, modifications, and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

CLAIMS

1. A vane-type rotary fluid displacing device including an external member co-operating with an internal member, the members being relatively rotatable about a common axis, the external member having an internal peripheral surface and the internal member having an external peripheral surface, the surfaces being opposed, one of which peripheral surfaces has a sinuous profile additionally including first and second arcs, the other peripheral surface having a substantially circular profile, wherein said member having the substantially circular profile has at least one diametrically opposed vane slidably received therein;

said first arc having a radius of curvature fractionally greater than a distance from the axis of rotation to said external peripheral surface of said internal member;

said second arc having a radius of curvature larger than that of said first arc by the extent of the maximum excursion of said vane beyond said other peripheral surface;

wherein said vane is adapted to continuously contact and sweep the peripheral surface of the other member, such that upon relative rotation of the members, the or each vane slides in the member having said other peripheral surface as the vane sweeps said one peripheral surface;

wherein the or each vane together with said peripheral surfaces form a plurality of chambers; and

an inlet provided in one said chamber and an outlet provided in another said chamber whereby, in use, fluid may be drawn into said one chamber through said inlet and discharged from said other chamber through said outlet by the sweeping action of said or each vane.

2. A device according to claim 1, wherein the external member is in the form of a housing, the internal peripheral surface of which has the sinuous profile to which has been added said first and second arcs, the internal member having substantially circular profile and a diametrally disposed vane slidably

mounted therein, the ends of which are adapted to continuously contact and sweep the internal peripheral surface of the housing.

3. A device according to claim 1 or 2 wherein the internal member is a substantially cylindrical rotor.

4. A device according to any one of claims 1 to 3, wherein the two arcs on the profile of the internal peripheral surface are separated by two half sine waves.

5. A device according to any preceding claim, wherein said internal member abuts or is adjacent to said internal peripheral surface along said first arc.

6. A device according to any preceding claim, wherein said first arc is situated between said inlet and said outlet.

7. A device according to any preceding claim, wherein said second arc is situated substantially diametrally opposite said first arc.

8. A device according to any preceding claim, wherein an inlet passage and an outlet passage extend outwardly and parallel to each other from said inlet and said outlet, respectively.

9. A device according to any preceding claim, wherein said housing has the form of a flattened cylinder.

10. A device according to any one of claims 3 to 9, wherein the housing has two chambers, each of which having said internal peripheral surface and the rotor and vane arrangement associated therewith.

11. A device according to any one of claims 1 to 10, wherein said external member is radially movable relative to said internal member.

12. A device according to claim 11, further including resilient biasing means for returning said external member to its original position after said radial movement.

13. A device according to any preceding claim, wherein a roller is provided on the ends of the or each vane where they contact said internal peripheral surface of the housing.

14. A ventricular assist device, including a vane-type rotary fluid displacing device according to any one of claims 1 to 13.

15. Use of a device according to any one of claims 1 to 13, as a ventricular assist device.

16. The use according to claim 15, wherein said device is located externally to the patient.

17. The use according to claim 15, wherein said device is used as a bridge to transplantation or in acute treatment for a failing heart.

18. The use according to claim 15, wherein said device is implanted into the patient.

19. The use according to claim 18, wherein said device is implanted into the thoracic cavity or abdomen of a patient.

20. The use according to claim 18 or 19, wherein said device is operated by an electro-mechanical actuation means which transfers energy transcutaneously via an indication loop.

21. A vane-type rotary fluid displacing device, substantially as herein described with reference to any one of the embodiments shown in the accompanying drawings.

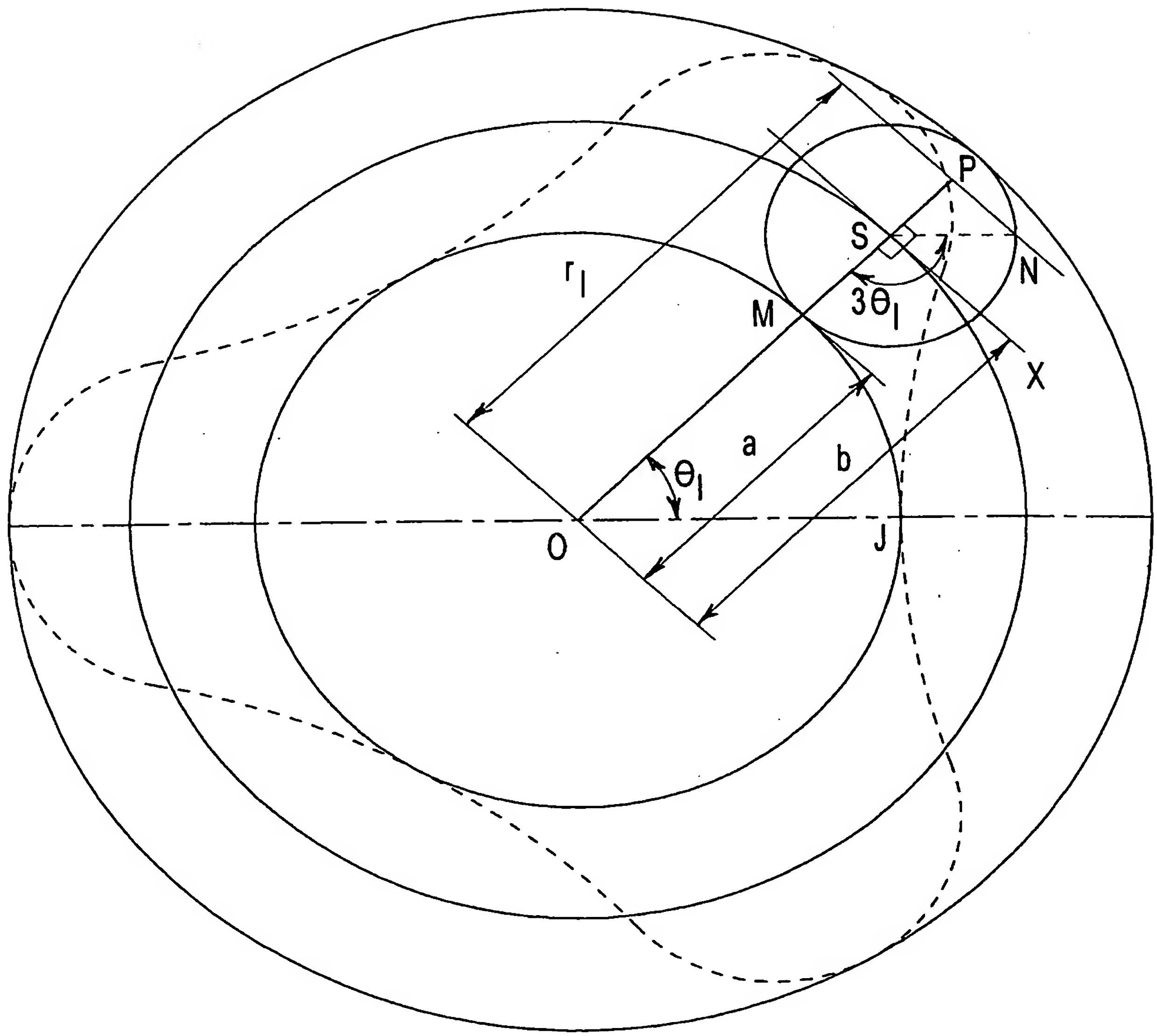


FIG 1

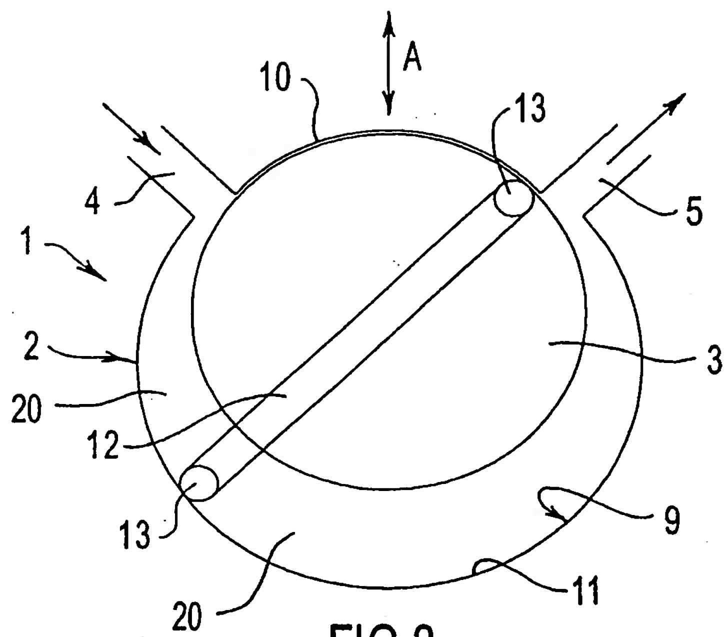


FIG 2

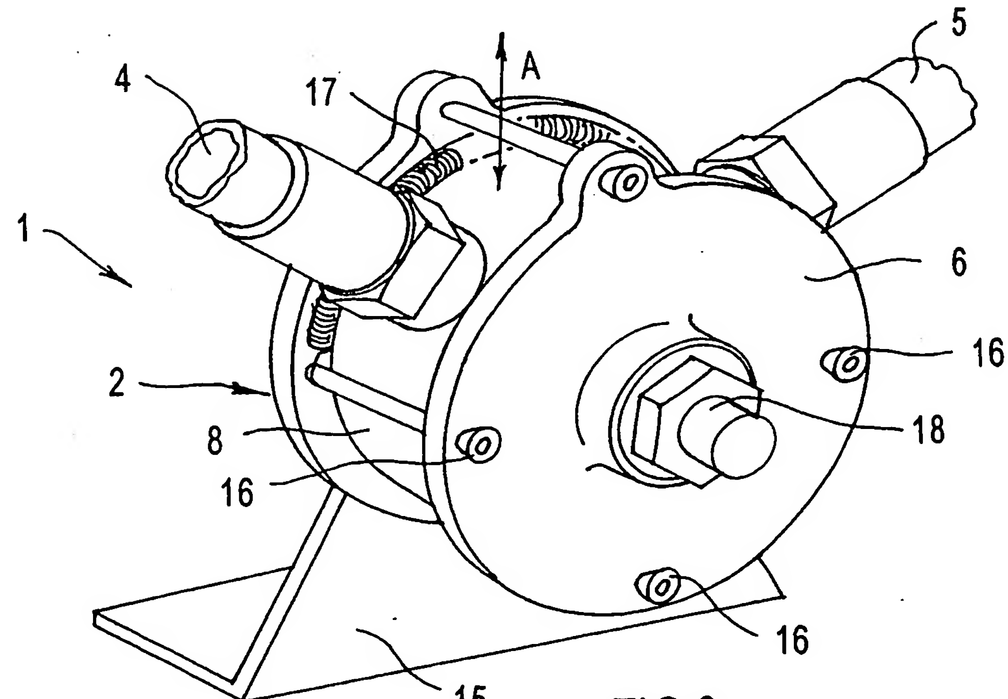


FIG 3

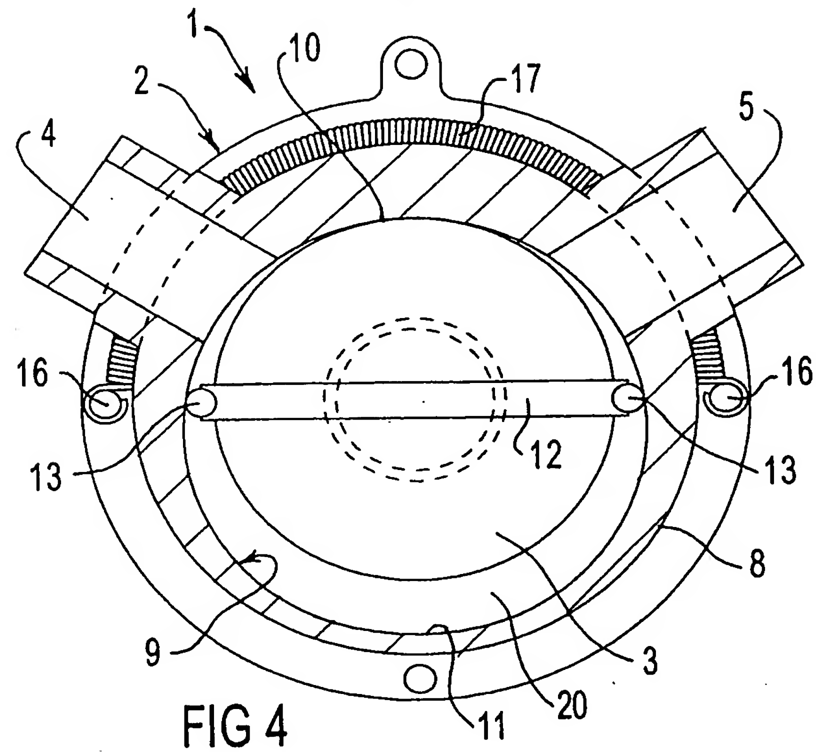

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FIG 4

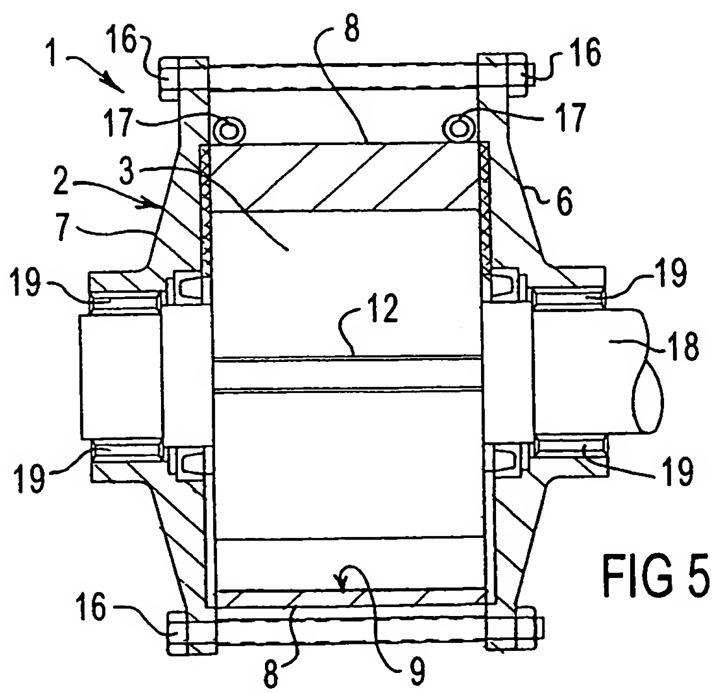
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FIG 5

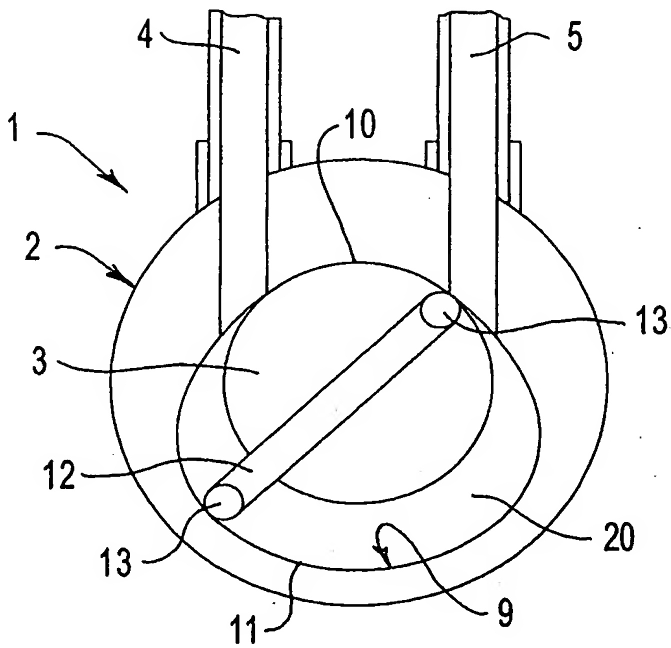

FIG 6

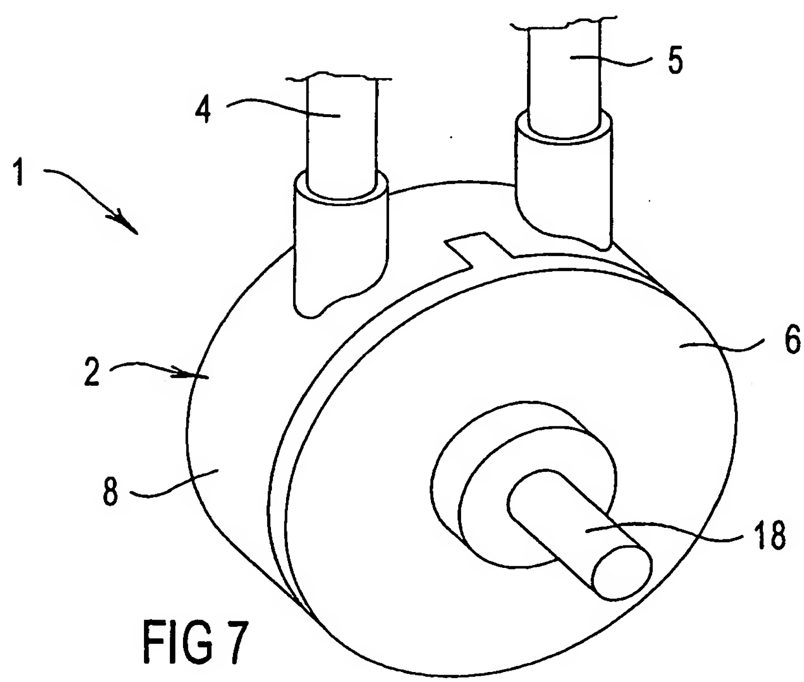

FIG 7

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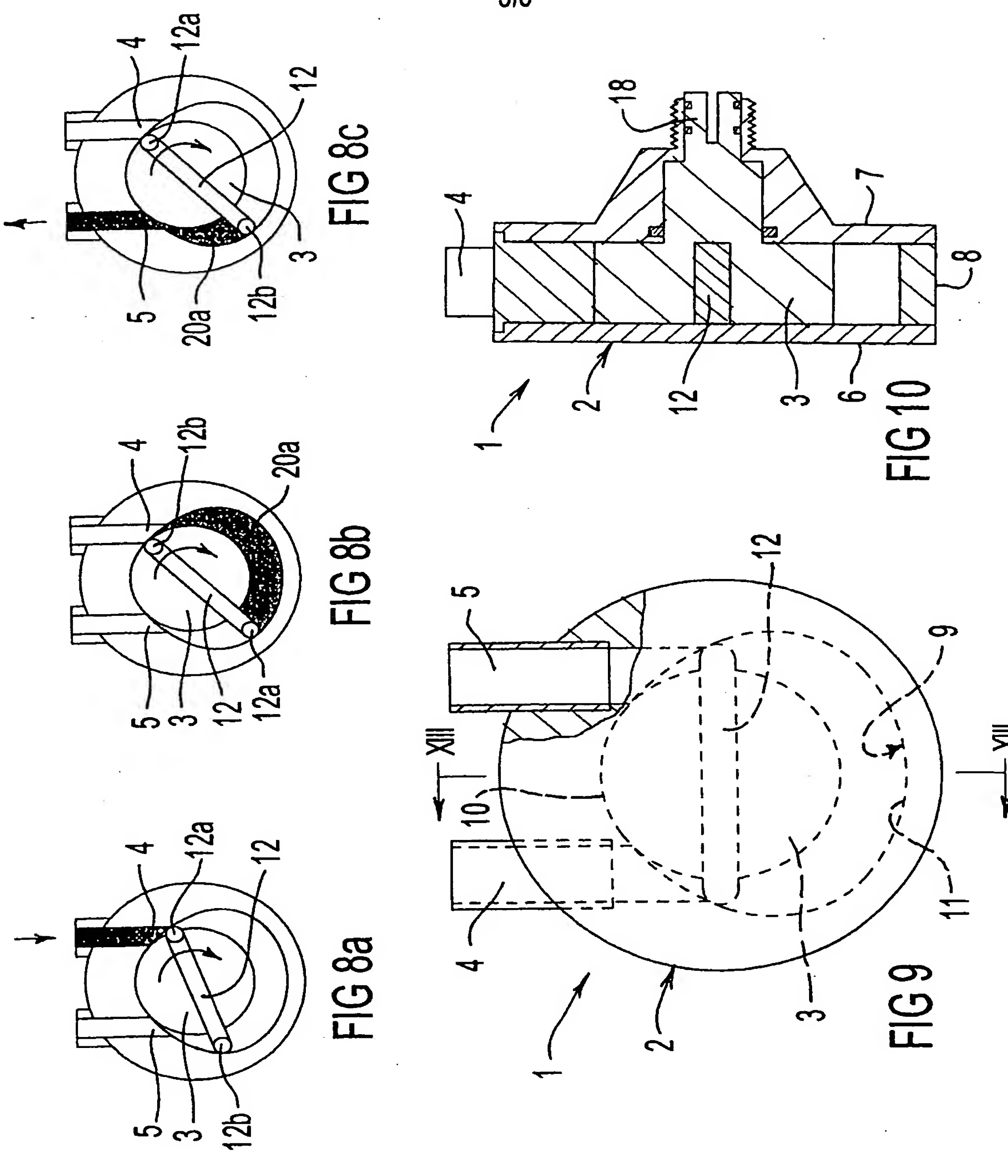

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 98/00186

A.	CLASSIFICATION OF SUBJECT MATTER
Int Cl[6]:	F04C 2/344. 15/00, 2/34, A61M 1/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC F04C 2/344. 15/00, 2/34, 18/344. 18/356, 18/34, 18/35, A61M 1/IC

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU:IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: radius/radii/diamet:/radia:, pump:/ vane#/blade#

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	DE 3812794 A1 (HAMMERLE) 26 October 1989	
X	column 3, line 29-column 5, line 30, claims	1-3, 5-12,14-20
Y	column 3, line 29 - column 5 line 30	4,13
	AU 43288/68B(OSTBERG) 4 March 1971	
Y	page 4, line 2 - page 5, line 20	4

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 1998	01 June 1998 (01.06.98)

Name and mailing address of the ISA/AU	Authorized officer
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C (Continuation)	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4712987 A (INOMATA) 15 December 1987 column 6, line 48 - column 7, line 10, figure 10,11	4
Y	Derwent Abstract Accession No 96-320224/32 Class Q 56, JP 08144975-A, 4 June 1996 Abstract and Figure	13
X	EP 333391 A2 (J.S. MASKINFABRIK A/S) 20 September 1987 column 3, line 24-column 4, line 22, figures 1, 2, claims 1,2	1-3, 5-12, 14-20
X	WO 94/05912 A1 (LORENTZ) 17 March 1994 page 16, line 23 - page 17, line 17, figures 3-5	1-3, 5-12, 14-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 98/00186

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
AU	43288/68	DE	1946794	FR	2017937	GB	1258983
		US	3642390				
US	4712987	AU	57606/86	DE	3616579	JP	61268894
		US	4712987				
EP	333391	DK	1441/88				
WO	9405912	CN	1103931	EP	659237		

END OF ANNEX